

# Dyspnoea is associated with pulmonary function impairment in exposed workers

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This study aimed to evaluate the prevalence of dyspnoea and its predictors in studies on several working male groups in British Columbia (BC), Canada (cedar sawmill, grain elevator, pulpmill, and aluminum smelter workers), and Tuscany (T), Italy, (shoe and furniture makers, millers, bakers, and pharmaceutical workers).

We performed cross-sectional health studies (interviews and pulmonary function tests) for 2498 BC and 1474 T workers exposed to air contaminants, and 1110 BC and 243 T controls.

Similar questionnaires and the same definitions were used in BC and in T. Pulmonary function tests were also performed. The participation rates were >92% in BC workers and >82% in T workers. The overall prevalence of moderate dyspnoea was not different in exposed BC and T workers in comparison with controls. Slight dyspnoea was significantly more frequent in BC workers, but not in T workers, with respect to controls. After adjusting for age, body mass index (BMI), smoking, current asthma, and chronic bronchitis, forced expiratory volume in 1 s (FEV<sub>1</sub>) and forced vital capacity (FVC) were found to be significantly associated with slight and moderate dyspnoea in BC workers, and slight dyspnoea in T workers.

Isolated dyspnoea is associated with reduction in FEV<sub>1</sub> and FVC in working populations, after adjusting for potentially confounding variables.

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## Introduction

Dyspnoea has been defined as 'an uncomfortable sensation of breathing' (1). It is a cardinal symptom of diseases affecting the cardiorespiratory system, with wide inter-individual variation existing between the degree of dyspnoea and the severity of the underlying respiratory disease (2). Dyspnoea is influenced by several factors, such as anxiety, fear, and physical activity. This considerable inter-subject variation has hampered attempts to relate dyspnoea perception to lung function tests (3). Although some authors have found that the dyspnoea rating did not correlate well with results of pulmonary function tests (4), most studies did not consider confounding variables such as age, body weight, smoking and type of work activity (3,4).

Moreover, the prevalence of dyspnoea and the correlation between dyspnoea and lung function tests have seldom been studied in a working population exposed to

environmental pollutants (5,6). In epidemiological studies, degree of dyspnoea has distinguished groups of workers exposed to different agents or with varying severity of airway obstruction (7–11). Whether this difference is still present when the prevalence of other predictors of dyspnoea is taken into account remains to be determined.

In this study we investigated whether dyspnoea is associated with pulmonary function impairment as expressed by FEV<sub>1</sub> and FVC in two different working populations exposed to air contaminants in British Columbia, Canada, and in Tuscany, central Italy. As controls, we studied workers employed in industries with minimum air contaminants. We then assessed the influence of several predictors (age, body weight, smoking status, current asthma, chronic bronchitis) on the relationship between dyspnoea and pulmonary function impairment. Furthermore, we asked whether the prevalence of dyspnoea was increased in the working populations with respect to control groups.

## Materials and Methods

### SUBJECTS

Data were derived from cross-sectional health studies of workers exposed to air contaminants known to be

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associated with respiratory symptoms (5–11). Those studies were conducted by the Occupational Lung Diseases Research Unit, Department of Medicine, University of British Columbia, between 1979 and 1982, and by the Respiratory Diseases Unit of the Italian National Research Council (CNR) Institute and University of Pisa, between 1985 and 1991.

In British Columbia (BC) there were 802 workers in a red cedar sawmill, 767 in four terminal grain elevators in the port of Vancouver, 461 in a pulpmill who were exposed to levels of gases (chlorine, sulphur dioxide, hydrogen sulphide, and methyl mercaptan) below threshold limit values (TLV), and 903 aluminum smelter workers who were also exposed to gases such as gaseous fluoride and sulphur dioxide, and particulate fluoride below TLV. The details of these studies had been reported previously (12–15).

In Tuscany (T) the following groups of workers were studied: 994 shoe-makers exposed to leather dust and solvent vapours, 485 furniture workers exposed to isocyanate vapours and wood dust, 293 millers and bakers exposed to flour dust and 264 pharmaceutical workers exposed to chemical compounds. Concentration of airborne occupational contaminants were below TLV in shoe-makers, furniture and pharmaceutical workers; in millers and bakers dust measurements showed values higher than  $10 \text{ mg m}^{-3}$  in unloading and packing areas. Part of the results of these studies have been previously reported (16,17).

In BC data from 1803 workers employed in industries with minimum air contaminants (4–10 times lower than exposed workers) were analysed as controls (12–15). In T, data from 243 subjects in the general population who were not exposed to air contaminants in the work-place were used as controls (16,17). The participation rate of BC workers in these health studies was 93–93.8%. In T workers the participation rates were: 85.0% in shoemakers, 91.5% in furniture workers, 87.3% in millers and bakers, and 82.5% in pharmaceutical workers. BC exposed and control workers were studied within 1 year of each other or simultaneously. T controls were studied in the same period (1985–1991) as exposed workers.

Women and non-Caucasians were excluded from the analysis because of the small numbers in most groups and the possible racial differences in smoking habits and atopy. In BC the results obtained in 616 cedar sawmill, 718 grain elevator, 388 pulpmill, 776 aluminum smelter (total 2498), and 1110 control white male workers are presented in this report. In T we examined 652 shoemakers, 431 furniture workers, 262 millers and bakers, 129 pharmaceutical workers (total 1474), and 243 controls.

## QUESTIONNAIRE

Each worker was interviewed by trained personnel, using a modified ATS-DLD-78 questionnaire (20) for epidemiological research in BC, and a modified Italian version of the standard National Heart and Lung Institute (NHLI) questionnaire (CNR questionnaire) in T (21). In the ATS-DLD-78 and CNR questionnaires the series of questions on breathlessness are essentially the same as in the British

Medical Research Council (MRC) questionnaire. The following definitions were used.

*Current smokers*: those who had been smoking at least one cigarette daily for the last 12 months.

*Ex-smokers*: smokers who had stopped smoking six months or more before the enrolment.

*Non-smokers*: all others.

*Slight dyspnoea or Grade 1 dyspnoea*: answer 'yes' to 'Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?' (Question #13A of the ATS-DLD-78 questionnaire) (17) and 'no' to 'Do you have to walk slower than people of your age on the level because of breathlessness?' (Question #13B).

*Moderate dyspnoea or Grade 2 dyspnoea*: answer 'yes' to both the above questions.

*Current asthma*: answer 'yes' to both 'Have you ever had asthma?' and 'Do you still have it?'.

*Chronic bronchitis*: answer 'yes' to 'Have you brought up phlegm from your chest on most days for 3 consecutive months or more in the last 2 years?'.

## PULMONARY FUNCTION TESTS

Lung function tests were performed according to the current American Thoracic Society recommendation. In BC a 13.5 l Collins water sealed spirometer (Braintree, MA, U.S.A.) was used, while in T flow and after integration volume, were measured using a pneumotacograph (Fleish No. 3. HP Pulmonary System, Waltham, MA, U.S.A.) connected to a computer. A minimum of three satisfactory forced expiratory manoeuvres was required of each subject. A satisfactory test required that the forced vital capacity (FVC) and forced expiratory volume in 1 s ( $\text{FEV}_1$ ) of two manoeuvres was reproducible within 5%. Analyses were performed on the largest FVC and  $\text{FEV}_1$  expressed as a percentage of the predicted value. Normal predicted values were derived from Crapo *et al.* (22) for BC and from an epidemiological survey in Northern Italy (23) for T.

## STATISTICAL ANALYSIS

The statistical analysis was performed at the University of Perugia and at the University of Pisa on personal computers using the SAS Statistical Package program (Version 6, SAS Institute, Cary, NC, U.S.A.). Analysis of variance and the chi-square test were used to examine differences between workers and controls. Logistic regression analysed the influence of age, body mass index (BMI), smoking status, working group, current asthma, chronic bronchitis, FVC and  $\text{FEV}_1$  (predictors) on dyspnoea (dependent variable). As regards working groups, the following were included: BC cedar sawmill, grain elevators, pulpmill and aluminum smelter workers, T shoemakers, furniture workers, millers and bakers, and pharmaceutical workers. For multiple logistic regression models, the results are given in terms of odds ratios (OR) with 95% confidence intervals (CI). Dependent and independent variables were binary (0=absence, 1=presence of the condition). Continuous variables ( $\text{FEV}_1$ , FVC, age, and BMI) were transformed

TABLE 1. Characteristics in studies of British Columbia and Tuscany workers

	BC controls ( <i>n</i> =1110)	BC workers ( <i>n</i> =2498)	<i>P</i> -value*	T controls ( <i>n</i> =243)	T workers ( <i>n</i> =1474)	<i>P</i> -value*
Age (years)	40.9 (12.3)†	39.7 (13.3)	0.014	38.1 (11.4)	38.4 (10.7)	n.s.
Height (cm)	176.9 (7.3)	176.3 (6.6)	0.03	172.5 (6.7)	172.6 (6.9)	n.s.
Weight (kg)	78.3 (11.7)	79.5 (10.8)	0.003	77.7 (10.9)	75.3 (11.2)	0.05
Employment duration (yr)	8.9 (7.9)	11.1 (10.1)	0.0001	17.1 (11.7)	18.8 (10.6)	0.01
Smoking habits			0.001			0.02
Current smoker (%)	40.5	47.5		39.5	47.0	
Never smoked (%)	29.6	23.0		26.3	26.7	
Ex-smoker (%)	29.9	29.5		34.2	26.3	
Slight dyspnoea or more (%) (ATS Q#13A)‡	13.6	21.4	0.001	15.2	17.6	n.s.
Moderate dyspnoea or more (%) (ATS Q#13B)‡	2.7	2.9	n.s.	2.5	2.5	n.s.
Current asthma (%)	2.3	2.9	n.s.	1.2	2.8	n.s.
Chronic bronchitis (%)	14.0	20.5	0.001	14.0	14.7	n.s.
FEV <sub>1</sub> (% pred)	97.5 (14.4)	94.4 (14.6)	<0.0001	101.5 (13.7)	99.2 (17.1)	0.05
FVC (% pred)	100.5 (12.7)	98.4 (12.8)	<0.0001	98.4 (12.1)	97.1 (13.2)	n.s.
FEV <sub>1</sub> /FVC (% pred)	97 (8)	96 (9)	<0.0001	103.5 (11.5)	102.3 (13.1)	n.s.

\*By ANOVA *F*-test (continuous variables) or chi-square (proportions). †Mean (SD).

‡ATS-DLD-78 questionnaire numbers (reference 20) are in parentheses.

BC=British Columbia; T=Tuscany; n.s.=not significant.

into categorical variables using the quartile distribution obtained separately for BC and T; in particular, the highest quartile (for age and BMI) or the lowest quartile (for FVC and FEV<sub>1</sub>) were associated with the presence of the condition.

In the first stage of the analysis the dependent variable was set to 1 for moderate and 0 for slight or no dyspnoea; the second stage focused on slight dyspnoea only (subjects with moderate dyspnoea or more were excluded) and the dependent variable was set to 1 for slight and 0 for no dyspnoea. To assess the significance of the effects of the different predictors, the (asymptotic) chi-square distribution of the log-likelihood test (G2) and the normal distribution of the parameter estimates were used (24).

## Results

### PREVALENCE RATES

The results refer to data from a total of 3608 BC and 1717 T white males. Table 1 shows the characteristics of BC and T workers compared with control groups. Prevalence in slight dyspnoea was significantly increased in BC workers vs. the BC control group, while no difference was observed between T workers and control subjects.

In both BC and T workers some predictors of dyspnoea (body weight, duration of employment, smoking habit, and FEV<sub>1</sub>) were significantly different from those of their respective controls. Moreover, in BC workers age was lower, prevalence of chronic bronchitis was higher, and FVC values were lower than those of controls.

### DYSPNOEA RATING AND PREDICTORS

Table 2 shows the distribution of predictors of dyspnoea rated in three grades. In BC and in T workers smoking and increases in age and BMI were associated with increasing severity of dyspnoea. The prevalence of current asthma and chronic bronchitis also increased with the severity of dyspnoea.

FEV<sub>1</sub> and FVC values declined as dyspnoea worsened both in BC and in T workers (Figs 1 and 2).

### FVC AND FEV<sub>1</sub> AS PREDICTORS

Logistic regression analysis yielded the predictive values of risk factors for moderate (Table 3) and slight dyspnoea (Table 4). After adjusting for age, BMI, smoking status, working group, current asthma, and chronic bronchitis, FEV<sub>1</sub> (OR 2.1) was found to be a significant predictor of moderate dyspnoea in the 126 BC workers in whom it was present. Of the four BC working groups, only occupation in the cedar sawmill was a significant predictor of moderate dyspnoea. The results of the other three BC working groups are not shown. Smoking status was not significantly correlated with FEV<sub>1</sub> when current asthma and chronic bronchitis were included in the model. In T workers there were only 29 subjects with moderate dyspnoea; FEV<sub>1</sub> was not a significant predictor of moderate dyspnoea in this group. None of the four T working groups was a significant predictor of moderate dyspnoea (results not shown).

After excluding the 126 BC workers and 29 T workers with moderate dyspnoea, we evaluated the relationship

TABLE 2. Dyspnoea rating in British Columbia and Tuscany workers

	British Columbia			Tuscany				
	None ( <i>n</i> =2924)	Slight (ATS Q#13A) ( <i>n</i> =558)	Moderate or more (ATS Q#13B) ( <i>n</i> =126)	<i>P</i> -value*	None ( <i>n</i> =1342)	Slight ( <i>n</i> =240)	Moderate or more ( <i>n</i> =40)	<i>P</i> -value*
Age (years)	38.8 (12.7)†	45.5 (13.1)	46.2 (13.0)	<0.0001	37.6 (10.5)	42.0 (10.9)	43.4 (11.3)	<0.0001
BMI (kg m <sup>-2</sup> )	25.2 (3.1)	26.1 (3.4)	27.5 (4.6)	<0.0001	25.2 (3.2)	26.4 (4.5)	26.5 (4.1)	<0.0001
Smoking habit				<0.001				<0.001
Current smoker (%)	42.9	58.4	44.4		44.2	54.4	57.5	
Never smoked (%)	27.8	12.7	15.1		28.3	17.3	15.0	
Ex-smoker (%)	29.3	28.9	40.5		27.5	28.3	27.5	
Current asthma (%)	1.9	3.8	17.1	<0.001	1.3	5.4	32.5	<0.001
Chronic bronchitis (%)	14.2	34.4	49.2	<0.001	11.6	26.4	60.0	<0.001

\*By ANOVA *F*-test (continuous variables) or chi-square test (proportions).

†Mean (SD).

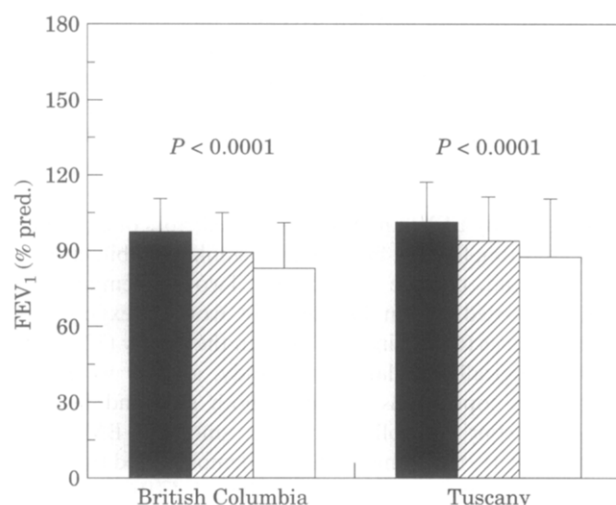


FIG. 1. Mean values (and SD) of FEV<sub>1</sub> (% predicted) in different degrees of dyspnoea in groups of workers from British Columbia and Tuscany. (■, no dyspnoea; ▨, slight dyspnoea; □, moderate dyspnoea).

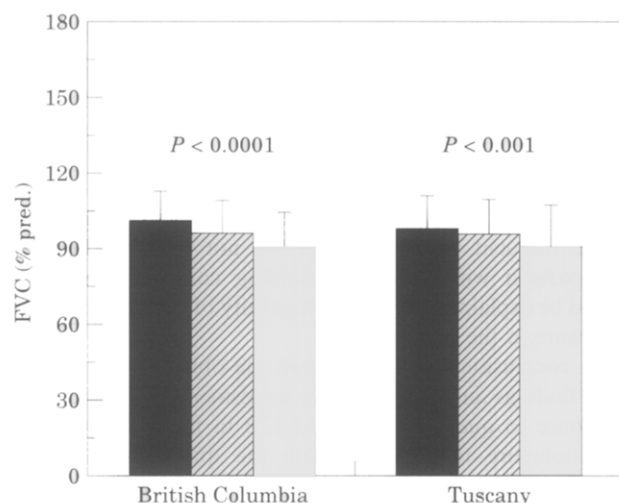


FIG. 2. Mean values (and SD) of FVC (% predicted) in different degrees of dyspnoea in groups of workers from British Columbia and Tuscany. (■, no dyspnoea; ▨, slight dyspnoea; □, moderate dyspnoea).

between FEV<sub>1</sub> and slight dyspnoea (Table 4). After adjusting for age, BMI, smoking status, working group, current asthma, and chronic bronchitis, FEV<sub>1</sub> was found to be a predictor of slight dyspnoea in both BC and T workers. In BC workers the predictive values of risk factors such as age, BMI, and chronic bronchitis overlapped with those for moderate dyspnoea (Tables 3 and 4).

Similar results were found when we used FVC or FEV<sub>1</sub>/FVC%<sup>-1</sup> predicted values instead of FEV<sub>1</sub> values as predictors (data not presented).

## Discussion

We demonstrated that dyspnoea is significantly associated with impairment of FVC and FEV<sub>1</sub> in a large group of

TABLE 3. Predictors of moderate dyspnoea (ATS Q#13B) simultaneously adjusted by logistic regression analysis in studies in British Columbia and Tuscany workers

Risk factor	OR	95% CI	P-value*
<b>British Columbia</b>			
FEV <sub>1</sub> <88% pred	2.1	1.4-3.2	0.0002
Age >51 years	1.5	1.01-2.2	0.047
BMI >27.2	2.6	1.7-3.8	0.0001
<b>Smoking habit</b>			
Current smoker	1.2	0.7-2.1	0.61
Ex-smoker	1.7	0.9-2.9	0.08
Cedar sawmill†	1.8	1.1-2.9	0.014
Current asthma	5.3	3.1-9.1	0.0001
Chronic bronchitis	4.0	2.7-6.0	0.0001
<b>Tuscany</b>			
FEV <sub>1</sub> <89.4% pred	1.1	0.4-2.6	0.9
Age >46 years	2.3	0.9-5.4	0.06
BMI >27.2	1.6	0.7-3.6	0.3
<b>Smoking habits</b>			
Current smoker	2.3	0.6-5.9	0.3
Ex-smoker	1.8	0.3-4.0	0.8
Current asthma	20.8	7.1-60.6	0.0001
Chronic bronchitis	6.0	2.6-14.0	0.0001

\*Comparison of proportion amongst workers with and without moderate dyspnoea by logistic regression analysis (those with slight dyspnoea considered together with those without dyspnoea).

†The effect of other working groups (grain elevator, pulp-mill and aluminum smelter workers) was not significant. In Tuscany no working group variables were significant.

workers, after adjustment for other predictors of dyspnoea, i.e. age, BMI, smoking status, working group, current asthma and chronic bronchitis. This relationship was consistent in workers from two different countries, who were exposed to different occupational risks but who were assessed using similar questionnaires.

The problem of bias and confounders must be addressed. In general, awareness among workers of occupational exposure to air pollutants may increase self-reporting of dyspnoea (information bias) (25). However, in this study, the link between a subjective respiratory symptom and objective measures of lung function seems to attenuate the power of the information bias.

As prevalence of dyspnoea depends on its definition, it is usually difficult to assess it and its predictors from studies carried out in different countries. However, in our study we used the same definitions in BC and T. We do not believe that the different pulmonary function test techniques have influenced the results and, indeed, the multivariate analyses carried out separately in BC and T support the consistency of results. In fact, methodological, instrumental and inter-individual differences (questionnaires, instruments, pulmonary function test technicians and dyspnoea perception) may be minimized by separate analyses in the two countries.

TABLE 4. Predictors of slight dyspnoea (ATS Q#13A) simultaneously adjusted by logistic regression analysis in studies in British Columbia and Tuscany workers

Risk factor	OR	95% CI	P-value*
<b>British Columbia</b>			
FEV <sub>1</sub> <88% pred	1.8	1.5-2.2	0.0001
Age >51 years	2.1	1.7-2.6	0.0001
BMI >27.2	1.5	1.2-1.9	0.0001
<b>Smoking habit</b>			
Current smoker	2.2	1.7-2.9	0.0001
Ex-smoker	1.6	1.1-2.1	0.005
Cedar sawmill†	1.5	1.2-1.9	0.0004
Current asthma	1.5	0.9-2.6	0.11
Chronic bronchitis	2.7	2.2-3.4	0.0001
<b>Tuscany</b>			
FEV <sub>1</sub> <89.4% pred	1.9	1.4-2.7	0.0001
Age >46 years	1.9	1.3-2.6	0.0002
BMI >27.2	1.8	1.3-2.6	0.0003
<b>Smoking habits</b>			
Current smoker	1.7	1.1-2.6	0.01
Ex-smoker	1.3	0.8-2.8	0.3
Current asthma	3.2	1.3-7.6	0.009
Chronic bronchitis	2.1	1.4-3.0	0.0002

\*Comparison of proportion amongst workers with and without slight dyspnoea by logistic regression analysis (those with moderate dyspnoea or more were included).

†The effect of other working groups (grain elevator, pulp-mill and aluminum smelter workers) was not significant. In Tuscany no working group variables were significant.

Moreover, cross-sectional studies of working populations tend to underestimate the prevalence of disease as sick or unhealthy workers usually leave the work-place (healthy worker effect). A strong selection bias seems improbable in this study because of the high overall participation rate.

Clinical experience suggests that dyspnoea is partially related to the severity of airway impairment (4,26). The complaint of dyspnoea has several physiological bases, some not strictly related to the severity of pulmonary function (2,3). A number of studies have demonstrated a correlation between dyspnoea and FEV<sub>1</sub> or FVC in asthmatics (3,4,27), subjects with chronic obstructive pulmonary disease (4,27-30) and in workers exposed to grain (5) and asbestos dust (31). These relationships have seldom been demonstrated in epidemiological studies. In the present epidemiological study, after adjusting for confounding variables, we have demonstrated that FEV<sub>1</sub> and FVC are good predictors of dyspnoea, suggesting that dyspnoea may be associated with a lung function impairment.

Pulmonary disease, old age, obesity, cigarette smoking, and working in a cedar sawmill are associated with an increased prevalence of dyspnoea and a lower FEV<sub>1</sub>. These are confounding elements which need to be adjusted for, in order to obtain an undistorted estimate of the correlation between dyspnoea and FEV<sub>1</sub> or FVC. In previous studies

on the relationship between dyspnoea and FEV<sub>1</sub> or FVC, conducted in asthmatic or COPD patients, the only confounding variables which had been taken into account were obesity and lung and heart disease (3,4). When investigating dyspnoea in workers exposed to air contaminants, Brodtkin *et al.* (31) adjusted for age, smoking, and working group, while Huy *et al.* (5) adjusted for age and smoking.

In our study FEV<sub>1</sub> and FVC were predictors of dyspnoea after adjusting for age, body weight, smoking habit, current asthma, and chronic bronchitis. Two epidemiological studies, carried out in Denmark in workers exposed to different dusts (6) and in the U.S.A. in the elderly (32), were methodologically similar to our study, as they were performed in populations including both sick and healthy subjects. After controlling for age, smoking, BMI, and work category, the Danish study (6) demonstrated that only Grade 3 dyspnoea or more on the British MRC scale was significantly related to FEV<sub>1</sub>. In the U.S.A. Enright *et al.* (32) showed that Grade 3 dyspnoea in the elderly was strongly associated with a lower FEV<sub>1</sub>, after adjusting for lung and heart disease, age, BMI, and smoking.

Few studies have investigated the prevalence of dyspnoea in working populations, taking into account other predictors. After adjusting for age, smoking habit, and airway hyperresponsiveness, dyspnoea was found to be increased in workers in synthetic fibre plants who were exposed to irritants (33), and in cement and blue collar workers after controlling for age and BMI (6). In some studies dyspnoea was associated with exposure to dust, gases, vapours or oil mist (6-11). In our study, slight dyspnoea was significantly more frequent in BC workers but not in T workers in comparison with the corresponding controls. This fact could be explained by the heterogeneity of the occupational exposure in the workers.

In conclusion the link between the objective lung function findings and the subjective assessment of dyspnoea in response to questions 13A and 13B in the ATS-DLD-78 questionnaire tends to validate the questionnaire to a certain extent. Furthermore, our findings tend to support the conviction that dyspnoea is not only a subjective symptom but may be a sign of underlying lung function impairment. Therefore we should not disregard this symptom in epidemiological surveys and in occupational settings.

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